

## Research of the method of calculating the area of a binary image

**Abstract.** Modern progressive information technologies are approaching one of the most important scientific and technical problems in terms of their capabilities - the creation of image processing and recognition tools. During the analysis of image information recognition methods, it was established that in reality not all information contained in the input stream of video data is essential (useful for decision-making), and that the selection and presentation of this essential information in an appropriate (depending on the task) form is central a problem for the area under consideration. A method for determining the area and orientation angle of a binary image with an irregular contour and its formalization are presented in the article. To implement methods for determining the area and orientation angle of binary images, a structure of optoelectronic homogeneous computing environments that perform the same type of operations simultaneously has been developed, which increases the productivity of the methods and allows to increase the speed of the calculation process. An experimental study and computer simulation of the method of determining the area of a flat figure, which is based on the principle of dividing the image into discrete sectors, was carried out.

**Streszczenie.** Nowoczesne postępowe technologie informacyjne zbliżają się do jednego z najważniejszych pod względem swoich możliwości problemów naukowo-technicznych – stworzenia narzędzi przetwarzania i rozpoznawania obrazów. W trakcie analizy metod rozpoznawania informacji obrazowych ustalono, że w rzeczywistości nie wszystkie informacje zawarte w wejściowym strumieniu danych wizyjnych są istotne (przydatne do podejmowania decyzji) oraz że selekcja i prezentacja tych istotnych informacji w odpowiedniej (w zależności od zadania) jest centralnym problemem dla rozważanego obszaru. W artykule przedstawiono metodę wyznaczania pola powierzchni i kąta orientacji obrazu binarnego o nieregularnym konturze oraz jego formalizacji. W celu implementacji metod wyznaczania pola powierzchni i kąta orientacji obrazów binarnych opracowano strukturę optoelektronicznych jednorodnych środowisk obliczeniowych realizujących jednocześnie ten sam typ operacji, co zwiększa produktywność metod i pozwala na zwiększenie szybkości procesu obliczeniowego. Przeprowadzono badania eksperymentalne i symulację komputerową metody wyznaczania pola powierzchni figury płaskiej, która opiera się na zasadzie podziału obrazu na dyskretne sektory. (Badanie metody obliczania pola obrazu binarnego)

**Keywords:** information technology, image information recognition, area, orientation angle, binary image, discrete angle, calculation error.  
**Słowa kluczowe:** technologia informacyjna, rozpoznawanie informacji obrazowych, powierzchnia, kąt orientacji, obraz binarny, kąt dyskretny, błąd obliczeń

### Introduction

Modern progressive information technologies are approaching one of the most important scientific and technical problems in terms of their capabilities – the creation of image processing and recognition tools at the level of human perception and thinking. The processes of informatization, acquiring a global character, are oriented not only on traditional approaches, therefore, the processes of creating the latest information technologies are significantly updated. For their further development, it is necessary to create formal methods of describing visual information in the context of the development of complex systems of transformation, processing and recognition of information.

In the process of operation of automated control systems, three stages are clearly observed. At the first stage, the task of recognizing the situation or phenomenon is solved, at the second stage, according to the criteria, a decision is made, at the third stage, the decision is implemented and management is carried out [1, 2]. Thus, recognition systems are the basis for the construction and operation of automatic and automated control systems of almost all classes. Image processing and recognition are widely used in various fields of science and technology, where various methods of processing, identification and recognition of two-dimensional and three-dimensional images are used.

### Analysis of visual information recognition methods

Nowadays, one of the promising directions of the development of modern technology is the creation of information support as part of automated control, intelligence and management systems [1, 2].

These systems include both telecommunications and data collection, processing, and analysis systems, and in

many cases, as an input stream of instrument surveillance information (scanning, photographing, locations, etc.) of relevant objects, territories, or scenes. In addition, video data plays the most important role for many tasks, such as navigation, technical diagnostics, cartography, geological exploration, etc.

Its high connectivity and structure is also of great importance for the automatic or automated solution of really intelligent problems based on video information. The fact is that images do not inherently change with small shifts, turns, and geometric distortions [3, 4, 5, 6]. At the same time, when registering images, as a rule, noise (obstacles) of various nature and intensity are superimposed on them [7, 8]. This means that in reality not all the information contained in the input stream of video data is essential (useful for decision-making), and that the selection and presentation of this essential information in an appropriate (depending on the task) form is a central problem for the area under consideration.

### The method of determining the area and orientation angle of a binary image with an irregular contour and its formalization

The area determination method is based on the discretization principle, where the image is divided into elementary sectors. The image is projected onto the input of the computing environment and moved in such a way that the center of the screen falls into the middle of the contour [9, 10, 11, 12]. Then rotate the image by 360° according to the selected contour and determine the discretization step  $\alpha$  corresponding to the elementary one. At each moment of time, determine the distance  $R_i$  from the reference center to the contour (Fig. 1) and calculate the area of the sector using the formula

$$(1) \quad S_{Sector_i} = \frac{\pi R_i^2}{N},$$

where  $N$  is the number of sectors.

The sum of the areas of all sectors corresponds to the area of the entire image

$$(2) \quad S_{image} = \sum_{i=1}^N S_{Sector_i}.$$

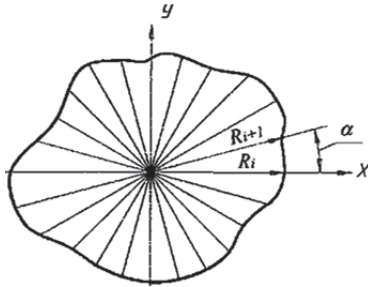


Fig. 1. Graphical model of determining the area of a figure with an irregular contour

Determining the orientation parameters of spot-like images [13, 14] is an important task for recognizing various freely oriented objects in computer systems that have optical channels for receiving visual information. Such parameters include, first of all, the coordinates of the center of the shape of the speckled image [13, 14] and its orientation angle [4, 5].

In the proposed method, the image is projected onto a discrete matrix medium, in which it is centered relative to the point  $O$ . The farthest point of the contour of the figure from point  $O$  is determined and a circle with radius  $R_{max}$  is drawn, and the closest point of the contour to point  $O$  is determined and a circle with radius  $R_{min}$  is determined. The circle with the radius  $R_{max}$  is divided into  $N$  sectors with a discrete angle  $\Delta\varphi$ . In each sector, the limited angle  $\Delta\varphi$  defines the area  $S_{1i}$ , which is located between the arc of the smaller circle and the contour of the image and the corresponding two radius vectors  $\rho_i$  and  $\rho_{i+1}$ . The area  $S_{2i}$  is also determined, which is limited by the contour of the image and a larger circle. Sectors are formed by rotating the figure relative to point  $O$  by a discrete angle  $\Delta\varphi$ . Thus, the part of the ring that is inside each  $i$ -th sector has two areas  $S_{1i}$  and  $S_{2i}$ , separated by the contour of the figure (Fig. 2).

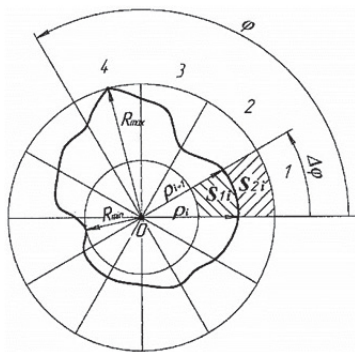


Fig. 2. Graphic model of the image and geometric parameters of the figure

Areas  $S_{1i}$  and  $S_{2i}$  are calculated according to formulas

$$(3) \quad S_1 = \frac{\pi(R_{max}^2 - \rho^2)}{N};$$

$$(4) \quad S_2 = \frac{\pi(\rho^2 - R_{min}^2)}{N},$$

where  $\rho = \frac{\rho_i + \rho_{i+1}}{2}; i = \overline{1, N}$ .

These areas are obtained after each rotation of the figure by an angle  $\Delta\varphi$  within  $R_{min}$  and  $R_{max}$  and then the ratio is determined

$$(5) \quad Q_i^F = \frac{S_{1i}}{S_{2i}},$$

which is compared with the reference one

$$(6) \quad Q_i' = \frac{S_{1i}'}{S_{2i}'},$$

where  $S_{1i}', S_{2i}'$  – area standards of figures.

The rotation is carried out until the parameters of the input image  $Q_i^F$  coincide with the parameters of the reference image  $Q_i^F \approx Q_i'$ .

At the moment of coincidence of the corresponding parameters, the number of discrete turns is determined, which characterizes the orientation angle  $\Phi$ :

$$(7) \quad \Phi = \{N \cdot \Delta\varphi : S_{1i} / S_{2i} \forall i = 1, 2, \dots, 2\pi / \Delta\varphi\},$$

where  $n$  is the number of sectors to which the image is rotated.

The accuracy of determining the angle depends on the selected value  $\Delta\varphi$ , that is, the smaller  $\Delta\varphi$  the greater the accuracy.

#### Development of an optoelectronic logic-time environment for determining the area of binary images

Works on the development and formation of optoelectronic homogeneous computing environments [15, 16] with the use of environments with normalized current consumption make it possible to get rid of the disadvantages inherent in television methods. The essence of such environments is that each processor element consumes a normalized amount of current, which indicates its level of excitation. In fig. 3 shows an optoelectronic homogeneous computing environment with normalized current consumption and an image projected onto it.

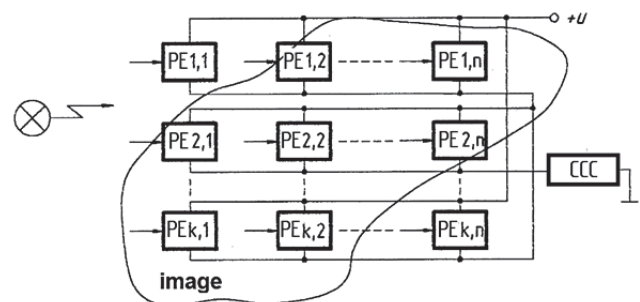


Fig. 3. Optoelectronic homogeneous computing environment with normalized current consumption: CCC – «current-code» converter; PE – processor element

Each processing element has its own optical input, which is combined with the inputs of the rest of the processing elements of the environment into a common input aperture, onto which the control image is projected. Each processing element consumes the same amount of current, which is summed up, passing through the «current-code» converter. At the output of the «stream-code» converter, a code is formed that reflects the number of processing elements that belong to the image. If the size of the aperture area of one processing element is known, then the image area is calculated.

The use of an optoelectronic homogeneous computing environment with normalized current consumption allows

you to calculate the image area in one machine processing cycle, but it cannot determine the area of contoured images without significant time expenditure.

New methods based on geometric approaches make it possible to increase the performance of an optoelectronic homogeneous computing environment when determining the area of images [16, 17].

The image is projected onto the input of the optoelectronic homogeneous computing medium, the center of which is aligned with the geometric center of the image. Then it is rotated by  $360^\circ$  relative to the center of the optoelectronic homogeneous computing environment, with a given discretization step  $\alpha$ , corresponding to the elementary one.

After each elementary turn, determine the distance  $R_i$  from the center of the turn to the contour and calculate the area of the sector according to formula (1). The sum of all the areas of the sectors corresponds to the area of the entire image (2).

The computing environment that implements this method is shown in fig. 4. Centering and rotation blocks center the image and rotate it sequentially. At each turn step, the distance from the center of the turn block to the contour point is projected onto a line of photodetectors, where a photodetector with a weighting factor corresponding to the distance  $R_i$  is triggered. The register and the counter form the  $R_i$  code and enter it into the computing unit, which performs calculations according to formula (1). In the accumulation adder, the sums of the elementary planes are accumulated.

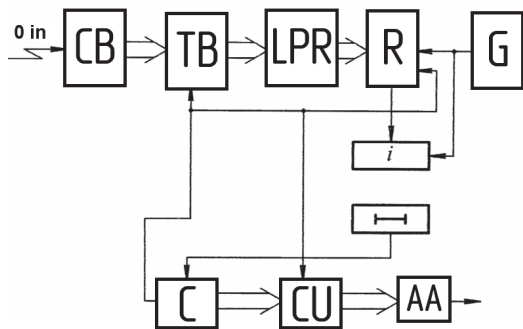


Fig. 4. Computing environment for implementing the method of determining the area of a figure: CB – centering block; TB – turn block; LPR – a line of photo receivers; R – register; C – counter; CU – computing unit; AA – accumulation adder; G – generator.

The considered methods are acceptable only for contour images, but can also work with solid ones. For this purpose, an optoelectronic homogeneous computing environment is introduced into the general structure to highlight image contours [11], which allows them to be highlighted in one cycle.

The contour selection is based on the analysis of the four neighboring cells of the environment with the selected point and, if all these cells are image cells, then the selected point is zeroed. All points are analyzed simultaneously, as are all nulls. The schematic diagram of one cell of the optoelectronic homogeneous computing environment for contour selection is shown in fig. 5.

The core of such a cell is a quantron with positive feedback that maintains it in an excited state. If there are zero signals at all inputs of the OR-logic element, then the quantron is zeroed due to shunting of the base-emitter junction of the VT transistor.

We will show the proposed method of determining the area in the form of an algorithmic model. Each operator vertex is implemented by a separate block of optoelectronic

homogeneous computing environment aimed at performing a given function. Each vertex of the model is considered as one action containing a sequence of operations. The second action of the algorithm is implemented in one cycle and its speed is determined by the time of operation of one cell of the optoelectronic homogeneous computing environment for selecting the circuit. The third action is characterized by the time of determining the geometric center of the image and the number of time cycles required to align the center of the screen with the center of the image. The execution of the fourth action depends on the sampling angle  $\alpha$  and the time spent on elementary rotation of the image. If you use an optoelectronic homogeneous computing environment with feedback implemented on a fiber-optic communication line, the twist of which gives the angle of rotation, then the rotation time will be equal to two durations of the switching on of the medium cell. The fifth action is determined by the time of searching for a cell at a specified address, and the sixth – by the time of adding the contents of the accumulating adder with the number at its inputs.

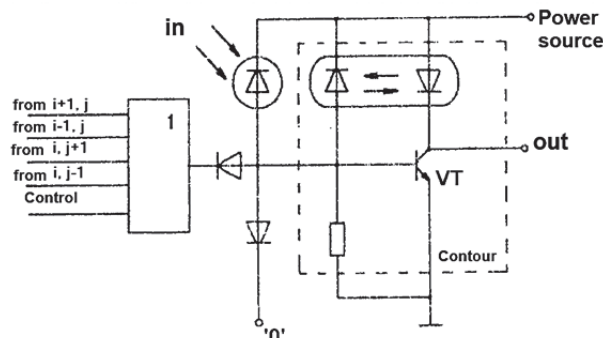


Fig. 5. Schematic diagram of one cell of an optoelectronic homogeneous computing environment for contour selection

The high performance of the proposed method is due to its high speed, due to the fact that discretization of the image by sectors of a circle always gives fewer machine cycles than during scanning.

If you use a continuous image to process it with this method, you must first perform the operation of selecting its contour.

### Experimental research of the method of calculating the area of a binary image

A program was created to determine the area of a binary image [17, 18]. Computer modeling of the computing environment was carried out for 100 different arbitrary images with an irregular contour [18]. For comparison, two options for calculating these areas using the formulas of sectors (1 and 2) and triangles (3 and 4) were performed.

Both calculation options were compared with the reference area of the figure and the calculation error was determined. The statistical analysis of the calculation error depending on the value of the discrete angle is shown in Fig. 6.

As can be seen from the graph, the error of area calculation by the triangle formula is higher than the error by the circle sector formula, but the nature of the fall of both curves coincides. Within the values of discrete angles from  $\alpha = 8^\circ$  to  $\alpha = 5^\circ$ , the curves have the smallest error value  $\varepsilon = 0.5\%$  and  $\varepsilon = 1.0\%$ . When the discrete angle  $\alpha$  is further reduced, the error begins to increase.

Experiments were also conducted to determine the center of rotation of the figure, at which the error is the smallest. The same figure with different coordinates of the center of rotation was chosen and its area was calculated.

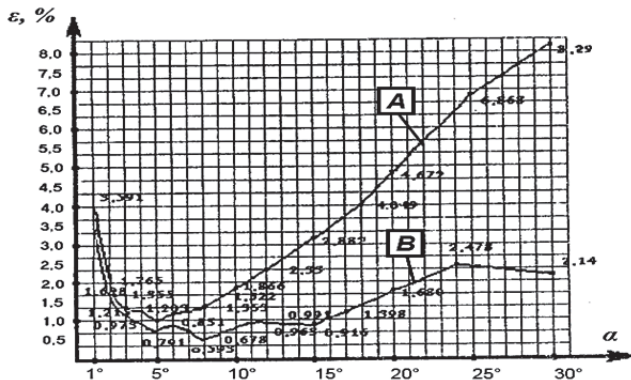


Fig. 6. Graph comparing the error of calculating the image area by the triangle (A) and sector (B) formulas

Computer modeling of this approach showed that the smallest calculation error is present when the turning point coincides with the geometric center of the figure, and can also be located in some area around this center. At the same time, the area can increase in direct proportion to the decrease in the angle of rotation.

The total time spent on determining the contour image area is determined by the following expression:

$$(8) \quad T_{total} = t_1 + t_2 + t_3 + t_4 + t_5 + N \cdot t_6 + t_7 + t_8,$$

where  $t_1, t_2$  – design time and contour selection, respectively;  $t_3$  – the time of determining the geometric center of the image;  $t_4, t_5$  – spending time on vertical and horizontal shifts;  $N = 360^\circ/\alpha$ ;  $t_6$  – the time taken to rotate the image by an angle  $\alpha$ ;  $t_7$  – the time of determining  $S_{sector}$ ;  $t_8$  – the time of addition by the accumulating adder.

The use of optoelectronic homogeneous computing environments for solving the given problem allows to obtain a total time equal to 3 ms (at  $\alpha = 1^\circ$ ), which increases the speed by 2.5 times compared to television methods.

## Conclusions

1. To implement methods for determining the area and orientation angle of binary images, a structure of optoelectronic homogeneous computing environments has been developed, which simultaneously perform the same type of operations, which increases the productivity of the methods and makes it possible to increase the speed of the calculation process by 2.5 times compared to television methods.

2. An experimental study and computer simulation of the method of determining the area of a flat figure, which is based on the principle of dividing the image into discrete sectors, was conducted. Within the values of discrete angles from  $\alpha = 8^\circ$  to  $\alpha = 5^\circ$ , the curves have the smallest error value  $\varepsilon = 0.5\%$  and  $\varepsilon = 1.0\%$ .

3. The use of optoelectronic homogeneous computing environments for solving the given problem allows to obtain a total time equal to 3 ms (at  $\alpha = 1^\circ$ ), which increases the speed by 2.5 times compared to television methods.

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